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Considering 'non-acoustic factors' as social and environmental determinants of health equity and environmental justice. Reflections on research and fields of action towards a vision for environmental noise policies

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ABSTRACT

Despite being an overall objective of European policies, health equity and environmental justice have not yet been systematically implemented in environmental policies. Taking control over one's environment as an element of health equity, we consider intractable exposure to transportation noise as a highly relevant policy field. The European Environmental Noise Directive is designed as a sectoral policy dealing with one environmental health determinant (noise) and drawing on the Global Burden of Disease framework, whereas health equity demands an investigation of the manifold variations in the population by combining adverse noise exposure with salutogenetic (psycho-)social and environmental resources. Such resources or the lack thereof have been referred to as 'non-acoustic factors' in noise- and soundscape-related research and can presumably account for vulnerability to transportation noise exposure caused by social and environmental determinants. Thus, we aim to link the current discourse on 'non-acoustic factors' with health equity driven by the need to go beyond average exposure–response-relations. After summarising challenges of environmental noise-related health impact assessment from a health equity perspective, we focus on residents' control – both procedurally and environmentally – to illustrate how social and environmental determinants can cause vulnerability. We advocate to consider 'non-acoustic factors' as leverage to promote health equity and environmental justice through three fields of potential action: (1) developing a theoretical and methodological groundwork and multi/interdisciplinary training of students and professionals, (2) introducing comprehensible information and

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inclusive participation methods, and (3) creating supportive institutional frames and governance modes. The contents of this paper were derived from a workshop held at the University of Bremen in September 2020.

1. Introduction

The link between social and health inequalities in Europe is persistent and is caused by unequal distributions of social and environmental determinants of health (cf. materials and publications on the Euro-HealthNet website). Urban and environmental planning institutions contribute to these distributional patterns through their plans and regulations and their failure to reduce health inequalities. Substantial parts of health inequalities are assumed to be 'unnecessary, avoidable, unfair and unjust' and also beyond individuals' control. These health inequalities are called health inequities and inseparably connected to distributional and procedural environmental justice. Though considered as universal and over-arching political objective, health equity has not been systematically translated into European policies and national transpositions.

As a chronic and intractable exposure, unremovable by individuals' 'isolated effort' (Campbell, 1983, p. 363), transportation noise can significantly reduce residents' control over their environment. Given the environmental health burden of transportation noise (WHO Regional Office for Europe / Joint Research Centre of the European Commission, 2011), the European Environmental Noise Directive (END) (European Parliament and Council, 2002) is an example of a policy with the potential to be highly relevant to equity concerns. While equity is intrinsically linked to social determinants, the END is a sectoral environmental policy focusing on one type of environmental determinant (pollutant) and tending to decontextualize population health. This is reinforced by environmental health impact assessments specialised on single exposures and based on the current Global Burden of Disease framework that requires standardisation worldwide regardless of local social, cultural and environmental particularities. The health equity perspective demands an investigation of the manifold variations in 'the' population by combining adverse noise exposure with salutogenetic (psycho-)social and environmental resources like perceived behavioural control and access to restorative areas. In other words, instead of looking at the population average, health equity raises awareness of unequal exposure distributions across settings relevant for people's lives and of unequal health outcomes (distributional environmental justice). In this vein, health equity calls attention to population groups likely to be at a higher risk of adverse health response, i.e. vulnerable groups (textbox 1).[1]

In this report, we discuss what is needed to develop a real-world understanding of exposure-health outcome-relations and to change the END into a more comprehensive policy tool effective for health equity. We begin by summarising the current state of health impact assessment in current END practice (section 2), highlighting challenges from an equity perspective (section 3). We suggest non-acoustic factors as entry points to introduce the health equity perspective in the END in addition to altering unfavourable noise exposure distributions (section 4); to advance health equity and environmental justice both in research and planning practice, we regard perceived procedural and environmental control as pivotal for a high trust environment. We delineate three fields of action (section 5): (1) developing a theoretical and methodological groundwork and multi-/interdisciplinary training of students and professionals, (2) introducing comprehensible information and inclusive participation methods, and (3) creating supportive institutional frames and governance modes (e.g. a joint accountability of environmental and urban planning departments for health equity).

This report results from discussions during an online workshop organised by the University of Bremen in September 2020, complemented by related research (supplement 1: workshop programme). The discussion results may set the grounds for a joint transdisciplinary research initiative in the future. Our expertise mainly refers to transportation noise exposure, but our arguments may also apply to situations characterised by other noise sources, like industrial, construction and wind turbine noise. Although transportation certainly represents the most prevalent noise sources, we acknowledge situations where issues of health equity, vulnerable groups and environmental justice are linked to these other noise sources rather than transportation noise. Whilst this report is developed in the context of the European Environmental Noise Directive, our discussion could apply internationally to the future development of environmental noise policies dedicated to environmental justice across the world. Thus, it addresses all those who are interested in moving environmental noise policies towards more health equity: researchers, policy-makers, officials, non-governmental organisations, and citizens.

2. State of assessing the impact of transportation noise exposure on health

According to Art. 12 of the END, European noise policy shall follow scientific evidence on assessment methods for noise indicators (Annex II) and for the harmful health effects (Annex III). Major progress regarding research and recommendations on harmful effects was achieved by the WHO Environmental Noise Guidelines for Europe in 2018 (WHO Regional Office for Europe, 2018). Derived from a series of systematic reviews (e.g., Basner and McGuire, 2018; Guski et al., 2017; van Kempen et al., 2018), the Guidelines were the basis for the revision of Annex III (Commission Directive (EU) 2020/367 of 4 March 2020), containing instructions to calculate general exposure–response-functions. The exposure indicators to be used are long-term exposure metrics incorporating sound pressures, frequencies and duration: L_{den} for the average sound pressure level during all day, evening and night periods and L_{night} for all night periods within one year (Annex I). To measure people's health response to transportation noise exposure, the number of people affected (NafP, e.g. percentage of the highly noise annoyed or sleep disturbed population) and disability-adjusted life years (DALYs) were chosen based on a Delphi stakeholder consultation as part of a methodological study on environmental noise and health assessment in the context of Annex III (van Kamp et al., 2018). The calculation of these two indicators was demonstrated in a case study. NafP was found to be a suitable indicator for tracking the health status in relation to transportation noise exposure over time and at variable spatial scales (where data is available). DALYs appeared as a useful summary measure covering life years lost due to premature deaths and life years affected by unfavourable health conditions attributable to source-specific transportation noise exposure.[2] The DALYs allow comparison of the source-specific exposure impacts across health outcomes and represent an overall burden of disease due to traffic-related noise, as demonstrated ten years ago by the WHO Regional Office for Europe and the Joint Research Centre of the European Commission (2011). DALYs are a familiar term among health practitioners and fit for broader impact assessment (including other sources of pollution), however they are less

[1] We acknowledge the variety of definitions and uses of the term 'vulnerability' that could be developed from the adverse exposure or people's health conditions / traits or both. Our conception is not meant to replace previous definitions, but to support the conciseness of our argumentation.

[2] The attributable fraction is estimated from the prevalence of noise exposure and exposure–response-functions (see, for example, Tobollik et al., 2019).

adequate for local problems and less understandable to those from other professions (e.g. planning practitioners) who work on the implementation of the END (van Kamp et al., 2018).

While noise annoyance and sleep disturbance as expressed by NafP are health outcomes specifically relevant for noise exposure, DALYs are used for health impacts assessments in various policies, thereby intending to facilitate informed decision-making when balancing different needs in contested political arenas as well as in contested local areas. Regardless of the health indicator used, their application will advance evaluation practice that currently decides on the changes in noise exposure levels attributed to only a single intervention measure, e.g. a reduction by 3 dB.[3]

3. Challenges from a health equity perspective

While acknowledging the progress in the field of transportation noise-related health impact assessment, we see challenges that need to be met in order to draw a complete picture of the general population and vulnerable population groups in relation to transportation noise exposure.

First, the laudable effort of scientific rigour by adhering to review guidelines and evidence grading tools inevitably leads to a lower grading of evidence from observational studies considered in the systematic reviews and WHO Environmental Noise Guidelines. The rigid approach of these reviews additionally favours diagnostically clear outcomes, which allows for cohort or case control study designs, whereas the evidence for a range of outcomes is still emerging and regarded as 'low quality' (e.g. cross-sectional study design). This is particularly true for cognitive, motivational, mental, and subjective health outcomes (Clark and Paunovic, 2018) that might be especially relevant for understanding the complex causality of noise health effects (e.g. noise annoyance, well-being, quality of life and of sleep, or sense of helplessness as mediating outcomes on the path to internationally classified diseases according to ICD codes). The body of evidence is too small and heterogeneous to infer exposure–response-functions for vulnerable population groups described by indicators of lower social position (e.g. background of specific migration/nationality, welfare dependency, educational attainment). Accordingly, 'the recommended guideline values might not lead to full protection of the population, including all vulnerable groups' (WHO Regional Office for Europe, 2018, p. 28).

Second, DALYs as a health indicator aim at comparability across time and regions. This implies that the selection of health outcomes based on internationally coded diseases as well as the degree of affectedness as expressed by disability weights are equally important everywhere irrespective of broader environmental, societal, cultural, or health care conditions (De Hollander and van Kamp, 2019). However, context-sensitive causality conceptions are needed to acknowledge the multi-dimensionality of health outcomes and relative validity of disability weights in different contexts. In particular, disability weights may need adjusting if adverse exposure accumulates and coping options are limited, thus leading to an increased vulnerability caused by social determinants among population groups.

Third, the noise indicators L_{den} and L_{night} have been contributing to establishing a valuable evidence base across Europe, as shown by the WHO Guidelines. They have proven to be pragmatic and seemingly simple 'one value'-indicators of long-term health effects. Nonetheless, they do not fully reflect actual exposure characteristics; completely different noise scenarios defined by the number and maximum levels of noisy events can result in the same equivalent level (Basner and McGuire, 2018). Moreover, they do not necessarily correspond with people's sound experience, making it challenging to describe the health relevance of L_{den} and L_{night} exposure values in plain words. Therefore, the indicators L_{den} and L_{night} have been criticised as insufficient to assess and protect population health (e.g. in regard to sleep: Basner et al., 2010; Haubrich et al., 2020a). Moreover, noise mapping according to END based on the noise indicators L_{den} and L_{night} still starts at 55 dB (A) and 50 dB (A), respectively, although exposure–response-functions suggest health effects below that exposure level. Again, this is particularly relevant for vulnerable groups (WHO Regional Office for Europe, 2009; 2018). The importance of striving for lower exposure levels and for accurate assessments of people's exposure experience is not conveyed by the spatial visualisation of current noise maps, which downplays the obligation to act according to the precautionary principle.

Fourth, the coverage of END noise exposure data is restricted to urban agglomerations and major infrastructures, yielding blank spots within countries. Furthermore, the quality may differ by agglomeration. Besides, the evidence of environmental noise health effects thus far has an uneven geographical distribution, resulting in a regional evidence

Textbox 1
: Our conception of vulnerability in this contribution

Vulnerability to environmental noise exposure can ensue from social, environmental, or biological determinants or the combination of the three. These determinants touch upon both distributional and procedural environmental dimensions of environmental justice. *Vulnerability* caused by social determinants can originate from lacking intra- and inter-individual cognitive and (psycho-)social resources. Regarding health equity, individual and collective control over one's environment including political participation, (property) rights and power to alter one's environment (e.g. taking protection measures such insulation) is a major psychosocial resource ('capability'), as explicated by Nussbaum (2010, 114). Accordingly, people's perceptions of environmental control are co-determined by the design of and residents' experience with planning procedures (procedural environmental justice). These perceptions are expressed by (missing) recognition, (mis-)trust in authorities and perceived (un-)fairness. Moreover, control over one's environment can be affected by a cumulation of stressors from other life domains (e.g. work and family life, financial strain and lacking opportunities). *Vulnerability* caused by environmental determinants can result from lacking resources like having no access to a stimulating environment or from long-term exposure to physical and chemical determinants in addition to transportation noise (e.g. air pollutants). *Vulnerability* caused by biological determinants relates to health outcome-specific increased risks due to traits, chronic illness, disabilities, or particular life stages (like critical time windows in children' s development, during pregnancy, etc.). We assume vulnerability from environmental, social and biological determinants can accumulate among identifiable population groups and are inter-twined through factual and perceived control over one's environment. Vulnerability is not an absolute characteristic of a particular population group, but a relational construct whose impact on (in-)equity becomes effective in context and may vary by health outcome.

[3] This may implicitly lead to a linear understanding of health effects as if a reduction of 3 dB were the same irrespective of the prevailing noise levels. However, most exposure-effect-functions are non-linear, and intervention measures need assessing based on the respective curves.

bias within Europe with fewer studies in Southern and Eastern Europe (European Environment Agency, 2020). Consequently, geographical differences in climate, culture (perceptions of noise exposure and behavioural responses), urbanisation level, and housing conditions could affect exposure and health responses. As a result of these challenges, exposure–response-functions that are currently available are not able to take context-specific factors and interventions into account, as suggested by observational studies investigating the (moderating) effects of features of the natural and built environment like greenness, access to a quiet side, room location, insulation, or ventilation (e.g. Foraster et al., 2014). Moreover, combined exposures cannot be integrated in health impact assessments based on 'single' exposure–response-functions. The European Commission is cognisant of combined exposures to noise in Annex III,[4] while research is still tackling this problem of 'context'. Annex III explicitly points to local specifics such as simultaneous exposure to multiple noise sources, availability of quiet façades / quiet sides, different climates / different cultures, and vulnerable groups of the population (without explaining how to grasp vulnerability and define these groups), but it does not offer instructions on what to do about these issues.

However, it is this context-dependency that the health equity perspective challenges us to focus on when studying exposure distributions across settings and health effects among those who are presumably vulnerable. Evidence is mixed and – when we consider the complexity of vulnerability caused by environmental, social and biological determinants – far from complete. Some studies show a social gradient as measured by deprivation and ethnicity (e.g. Mueller et al., 2018), whereas others observe differences in patterns between cities, by noise source and by the indicators used to define population groups (e.g. Robinson et al., 2018; Tonne et al., 2018).[5] Findings appear to depend on the content, quality, and scale of indicators used as concluded by a recent systematic review on social inequalities in environmental noise exposure (Dreger et al., 2019). Overall, it is difficult to summarise findings as there are methodological differences between studies concerning the assessment of noise exposure, scales, populations and the sociodemographic and socioeconomic indicators investigated (Barnes et al., 2018; Dreger et al., 2019). Most evidence is derived from cross-sectional studies, which does not allow to capture socio-spatial dynamics and changes in environmental qualities, health outcomes and disease distributions. Furthermore, apparent distributional inequalities at the disadvantage of particular population groups could be levelled up or reversed if variables like personal exposures across settings, perceived constraints and coping options were known and could be included. Health inequities may not only ensue from differences in exposure to environmental noise and environmental resources, but also from differences in vulnerability to environmental noise (Barnes et al., 2018; Bolte et al., 2011; Science for Environment Policy, 2016; European Environment Agency, 2018, 2020). Causes of vulnerability to transportation noise and their interplay are, however, rarely elaborated on and need further exploration.

Despite all these limitations in the evidence base, current research overviews (Barnes et al., 2018; Dreger et al., 2019; European Environment Agency, 2018, 2020; Science for Environment Policy 2016) present a disproportionate share of adverse noise exposure plus an increased vulnerability to transportation noise among materially disadvantaged citizens as likely.[6] Against this background, we turn to research insights from socio-environmental psychological and epidemiological research on 'non-acoustic factors'.

4. 'Non-acoustic factors' as determinants of vulnerability to transportation noise exposure

Socio-environmental psychological and epidemiological research has stressed the importance of dealing with exposure and effect differentials that are shaped by multiple combinations of health determinants. This is reflected by our conception of vulnerability as being caused by environmental, social and biological determinants (see section 1). These determinants – in noise and soundscape research often referred to as 'non-acoustic factors' – can make an essential difference particularly in settings where vulnerable population groups spend much of their time and / or environmental noise exposure is hard to change. A key issue is therefore to define and recognise 'non-acoustic factors' as opportunities for intervention to contribute to more health equity. Based on a preliminary definition of 'non-acoustic factors' (textbox 2), we describe research strands on modifiable 'non-acoustic factors' that can underlie vulnerability to transportation noise exposure caused by social and environmental determinants, focussing on the aspect of residents' control over their environment. In fact, perceived traffic noise control has been considered as important factor of subjective responses to noise for decades (Baum et al., 1981; Flindell and Stallen, 1999; Guski, 1999; Glass and Singer, 1972; van Kamp, 1990; Sherrod et al., 1977; for a review: Evans and Stecker, 2004).

4.1. *Social determinants of vulnerability to transportation noise exposure*

As implied by our assumed inter-relation between vulnerability caused by environmental, social, and biological determinants, causality of noise effects is rather complex. Drawing on the health map by Barton and Grant (2006), a very recent narrative review shows how the relationship between transportation noise exposure and people's response is embedded in social determinants of health (Peris and Fenech, 2020). Exposure to transportation noise and people's subjective response can interfere with health determinants like people's recreational and learning activities, health-related behaviour (attributed to lifestyle), property prices (attributed to local economy). These health determinants are typical candidates for 'non-acoustic factors' accountable for moderating transportation noise effects.[7] It is likely that these health determinants can affect non-acoustic psychosocial factors like social networks and coping options as relevant resources of perceived environmental control, which can increase vulnerability in the long run.

[4] Annex III says 'The exposure of the population shall be assessed independently for each noise source and harmful effect. Where the same people are simultaneously exposed to different noise sources, the harmful effects may -in general- not be cumulated. However, those effects may be compared to assess the relative importance of each noise' (EU Annex III CELEX_32020L0367_EN_TXT).

[5] For example, neighbourhoods with higher social position are those with highest noise exposure in Barcelona (Robinson et al., 2018). In London, exposure to aircraft noise was most prevalent among individuals with the highest household income, white ethnicity, and with the lowest area-level income deprivation. Exposure to railway noise was more frequent among black compared to white individuals (Tonne et al., 2018).

[6] Material disadvantage is connected to the place of residence and environmental quality. "Generally, where people live is a major driver for disparities relating to exposure to noise and air pollution, […]" (Barnes et al., 2018, p. 19). Vulnerability to transportation noise exposure can plausibly originate from a cascade of (material) disadvantages across determinants of health in the life-course, be it lacking access to quiet façades, shielding green space and insulation measures, or unhealthy diet, job insecurity, unsafe working conditions and shift work. 'Vulnerable groups' in relation to transportation noise as compiled by the European Environment Agency (2020, table 4.2, p. 56) are children, elderly, shift workers, pre-existing health conditions, noise sensitive, pregnant women, and socioeconomically disadvantaged. These group characteristics represent social, environmental and biological determinants of vulnerability and, as mentioned in textbox 1, probably coincide, thereby leading to multiple jeopardies.

[7] Thus, we probably cannot exclude 'non-acoustic factors' to be totally independent of transportation noise exposure.

Textbox 2
: Preliminary definition of 'non-acoustic factors'

A scientific consensus on a definition or a classification of 'non-acoustic factors' has not yet been reached. An initiative currently underway ('Characterising non-acoustic factors for acoustic, soundscape quality and annoyance assessments' as subject of a new ISO Technical Standard (ISO TC/43/SC1/WG62, Fenech et al., 2021)), however, offers a preliminary definition: Non-acoustic factors are 'All factors other than the objective, measured or modelled acoustic parameters which influence the process of perceiving, experiencing and/or understanding an acoustic environment in context, without being part of the causal chain of this process'. This means that 'non-acoustic factors' add to or alter the strength or even the direction of effect of the acoustic parameters on a selected health outcome. This moderation effect is linked to the higher risk of adverse health response that features 'vulnerability'. Ideally, 'non-acoustic factors' are not associated with the exposure and are, therefore, not only another (preliminary) response to the exposure.

The term 'non-acoustic factors' has been criticized as too broad and unspecific, encompassing any other aspect than mere decibels and ranging from personal factors (e.g. noise sensitivity and attitudes towards the noise source) to situational factors (e.g. access to a quiet side / facade) and contextual factors (e.g. procedural fairness, process around changes in noise exposure). Practically, the term 'non-acoustic factors' includes acoustic aspects, as well (as illustrated by the acoustic effect of a quiet side, for example) and is therefore partly incorrect. It is not the objective of *this* contribution is not to discuss different definitions and classifications. Instead, we would like to draw attention to factors that might be considered as environmental and social determinants of vulnerability and are modifiable towards more health equity and environmental justice. For instance, inclusive participation could be seen as a social determinant and access to quiet areas as an environmental determinant of vulnerability, both operating via perceived control over one's environment.

However, evidence on the relationship between objective and subjective noise exposure and cognitive and (psycho-)social resources is still scarce. Cognitive and (psycho-)social resources may have the potential to be relevant not only for health outcomes, but also for active engagement with the social and physical environment as determinants for participation in planning procedures.

Only recently, negative associations of exposure to road traffic noise (L_{den}) with neighbourhood-related communal mastery and engagement-related self-efficacy as determinants of intended and performed engagement were reported among older residents in the Ruhr Area (Riedel et al., 2021a). These negative effects tended to be more pronounced among female participants in this study. One mechanism proposed may work via a lack of perceived traffic noise control (Riedel et al., 2017a). However, the negative associations were present in spite of variables measuring feeling helpless in relation to exposure to noise exposure at home (reversed to be suggestive of perceived traffic noise control) and its personal importance in the respective equations of the cross-sectional path analysis (Fig. 1). These two variables (feeling helpless and personal importance of perceived traffic noise control) tended to be statistically less relevant for engagement-specific and communal mastery among those with lower education and living in neighbourhood surroundings with higher social welfare needs. Research needs therefore lie with figuring out social differences in explanatory contributions of psychosocial and cognitive variables.

Further, generalised self-efficacy, perceived traffic noise control and personal importance were statistically associated with engagement-specific self-efficacy and communal mastery which were related to intended engagement (Fig. 1). Both engagement-specific self-efficacy and intended engagement were statistically linked to performed engagement. Results from a small subsample indicated that

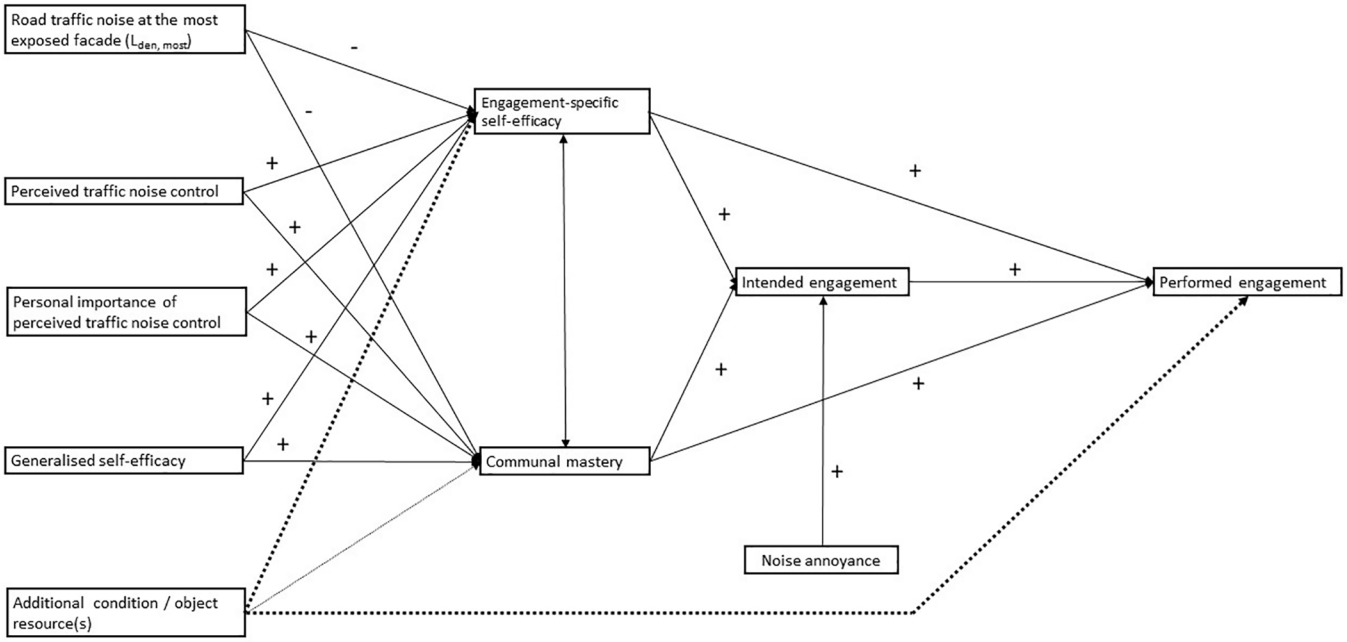

Fig. 1. Path model on civic engagement in the context of environmental justice **Legend:** Mathematical signs indicate the hypothesised direction of the association (+plus positive / - minus negative association). The additional paths related to resources in the core model are shown by dotted lines. The paths from the additional resources can have both signs (e.g. positive for social networks, negative for hearing-related comprehension problems), source (Riedel et el., 2021a).

engagement-specific self-efficacy and communal mastery were increased among those who perceived their civic engagement as effective. Social stratification by levels of social welfare in the neighbourhood disclosed the direct effect of engagement-specific self-efficacy on performed engagement to be stronger among those living in more affluent neighbourhood surroundings, while the opposite was the case for the indirect path from engagement-specific self-efficacy to intended engagement. For both subgroups (low vulnerability due to higher education and lower neighbourhood welfare), 'specificity of information on intervention opportunities of environmental planning, raising awareness on how noise can affect health and elucidating how perceived traffic noise control could be enhanced, both objectively and subjectively, could be the key' (Riedel et al, 2021a, p. 20). This might be particularly true for the 'Second Level Digital Divide' pointing to an educational gradient in political activity on internet platforms (the higher the education, the higher the activity) (Najemnik, 2018). Consequently, the e-participation increasingly used for noise action planning is likely to generate health inequities. Participation barriers and risks (registration procedure, anonymity / pseudonymity, and lacking discourse quality in deliberative approaches mostly dominated by 'professional citizens') typically result in a social participation bias (over 40, male, academic) (Böhnke, 2010).

In view of the participation aspect of social determinants of vulnerability, the Model On households' Vulnerability towards their local Environment (MOVE) (Köckler, 2017) has produced valuable insights – both theoretically and empirically. Against the background of air and noise pollution, MOVE was developed to explain residents' intending and performing actions in the environmental justice context (Fig. 2). MOVE builds on Ajzen's Theory of Planned Behaviour (TPB) (Ajzen, 1991). In this theory, attitude towards an institutional engagement, subjective norm regarding the perceived expectation of relevant others (family, peers, etc.) to one's behaviour as well as perceived behavioural control (engagement-specific self-efficacy or knowledge) predict intended institutional engagement. Both perceived behavioural control and intended engagement translate into reported actual engagement that, in turn, are promoted or impeded by factual behavioural control described by resources. In the MOVE model, these resources are framed by Hobfoll's Conservation of Resources (COR) Theory (Hobfoll, 1989) and include conditions (e.g. age, gender, education, occupation, health status), objects (home ownership), energy (income) and personal resources (communal mastery). The TPB predictors and COR resources stand for 'non-acoustic factors' as social determinants of vulnerability to noise exposure. For example, the attitude towards the noise source could be understood as behavioural predictor, while the personal benefit of being employed by the source authority or company producing the noise and communal mastery could be easily integrated as condition or personal resources, respectively. Moreover, indicators typical to describe social positions are not reduced to the confounding role in MOVE, but are worth investigating in their own right as meaningful condition resources relevant for engagement behaviour. In principle, MOVE was statistically confirmed by results from an empirical test in a population-based quota sample retrieved from the German Ruhr Area (Köckler, 2017). MOVE can therefore contribute to explaining procedural justice, i.e. coexisting up- and downwards loops in environmental quality caused by over-/underrepresentation depending on social positions (Köckler, 2017).

A perceived lack of control over resource maintenance and subsequent resource depletion is a stress-based mechanism plausibly effective in various life domains, as behavioural expectancies learned in different life domains across one's life-course may influence each other (Riedel et al., 2017b in reference to the Cognitive Activation Theory of Stress (Ursin and Eriksen, 2004, 2010)). Generalised expectancies of behavioural outcomes like helplessness and of uncontrollable stress stimuli can promote or impede cognitions related to engagement behaviour. However, the evidence of the joint or synergistic effect of transportation noise exposure, subjective noise responses and (psycho-)social resources from other contexts is at an early stage and needs further theorising, in particular regarding their contribution to health inequities as hypothesised and studied in social epidemiological models (e.g. work stress or self-efficacy as an explanatory determinant of health inequalities). For example, studies have reported additive effects of work- and

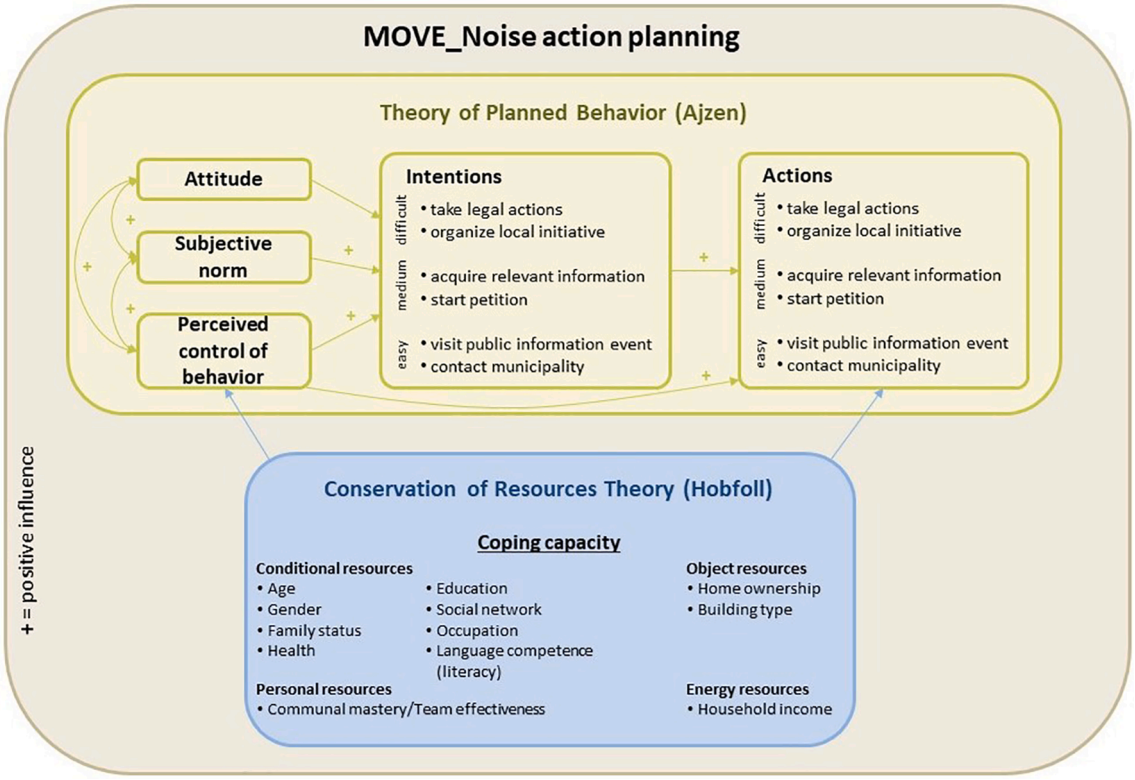

Fig. 2. The MOVE model applied to noise action planning (adapted from Köckler, 2011).

transportation-related exposures (Bartels et al., in press; Riedel et al., 2017b; Selander et al., 2013). Occupational status as a dimension of social position can result in a double burden of both residential and occupational noise exposure that can additionally diminish participation opportunities.

4.2. Environmental determinants of vulnerability to transportation noise exposure

The narrative review on the wider determinants of transportation noise effects from Peris and Fenech (2020) confirms the buffering health effect of audio-visual features of the natural and built environment (e.g. access to a quiet façade / side, cf. material and publications on the Qside website, as well as green and blue spaces and natural sounds, cf. van Kamp et al., 2016; Markevych et al., 2017). Conceptual ideas (Andringa and Lanser, 2013; van den Bosch et al., 2018) and empirical findings (Payne and Bruce, 2019) from sound- and sensescape-related research broaden our understanding of environmental quality and their effect on mind-states and activities.

Sound propagates in all directions and almost all mechanical interactions produce at least some sound (Gaver, 1993). These properties ensure that subtle sounds can inform us of activities in the immediate environment, while louder sounds inform us (typically) of more distant events (Andringa and Lanser, 2013; Job, 1999; van den Bosch et al., 2018). More specifically, environmental sounds can indicate safety and danger and are as such important motivators: in safety, individuals may relax or engage in fully self-selected activities that proactively transcend the here and now, while in the absence of (assumed) safety, individuals must reactively attend the here and now to re-establish safety or, at the very least, be continually alert. A safe environment constrains behaviours much less than an environment in which safety cannot be sensed or that is actively unsafe, hence an audibly safe environment is strongly preferred over one that is not.

It seems that subtle sounds associated with the activities of other individuals (human or animal) engaged in unforced or unconstrained behaviours are generally deemed pleasant: the sounds of relaxed pets and farm animals, singing birds, or family members, house-mates, and friends engaged in quiet activities are usually deemed relaxing and pleasant and the associated environment is described as calm. These sounds inform the first stages of auditory processing in other individuals in the vicinity that consider the situation safe enough to engage in self-selected activities. This convinces the listener of audible (and, in general, environmental) safety and spurs to engage in similar unforced activities. These unforced activities can also be more vibrant and active such as is the case in many social situations described as lively, where audible safety is similarly derived from (an abundance of) audible indicators of unforced behaviour.

Stationary sounds, like air-conditioners or the hum of distant traffic, tend to mask (subtle) indicators of audible safety and degrade environmental quality towards monotony or deficiency. Transient masking sounds such as passing scooters, cars, and aircraft not only temporarily mask indicators of safety, but they all have looming qualities indicative of approaching (potential) danger and hence they arouse, draw attention, disturb, and annoy. Where the masking effects of stationary sounds lead to monotony and deficiency, the masking effects of these transient sounds contribute to a sense of chaos (van den Bosch and Andringa, 2014), because it becomes difficult if not impossible to track all the activities in the sonic environment, which activates a perceived lack of control (stress) or even anxiety (van den Bosch et al., 2018).

The auditory nervous system is intimately connected to the parts of the midbrain associated with arousal and emotions (van den Bosch et al., 2018). This could lead to the assumption that the midbrain (with help of the cortex) continually responds to the acoustic aspects of sounds and also to its deeply programmed affectual, arousing, and attention-grabbing aspects.

The ways to conceptualise soundscape descriptors or soundscape dimensions (Axelsson et al., 2010; Cain et al., 2013) refer to meaning attribution through activating situation appropriate behaviour via an underlying construct called core affect (Russell, 2003).

As Andringa and Lanser (2013) and van den Bosch et al. (2018) reason from their theoretical considerations, the emotional and cognitive response to environmental appraisal in terms of 'how we feel, plan, and act' (core affect) results from two nested two-dimensional spaces at 45-degree angles. One 2D set (Axelsson et al., 2010) corresponds closely to core affect (Russell, 2003) and is spanned by environmental valance and eventfulness (or pleasure and arousal in the core affect domain). The valance axis corresponds to avoidance (on the left side) and approach on the right side of Fig. 3. Typically, we aim to avoid or end situations on the left while we aim to maintain or aim for situations on the right. The eventfulness axis corresponds to a measure of events per unit time. In the figure uneventful is at the bottom, while eventful at the top indicates the highest possible events that can be attributed behavioural significance (meaning) per unit time. An even higher event-rate leads to insufficiently processed events and a sense of a lack of perceived control (stress).

The second 2D set, with axes at 45-degrees has a first axis indicating a lack of or abundance of indicators of audible safety and spans monotonous to lively. A monotonous or deficient environment misses or masks indicators of safety and activates self-protection and an urge to avoid the environment. A lively or exiting environment is abundantly safe and interesting and stimulates learning and active engagement. The second axis of this set spans calm to chaotic. A calm environment allows easy estimation of audible safety and leaves ample mental resources available for proactive activities like caring for self or others. In contrast, chaos prevents the estimation of audible safety or is outright indicative of danger. This environment activates distress and aggression and prepares to fight or retain or regain control in other ways. A chaotic environment erodes the resources that have been built in a calm environment.

4.3. Link between social and environmental determinants of vulnerability via control

Audible safety can be considered as the positive and more comprehensive counterpart to previous environmental conceptions of noise-induced helplessness (e.g., Evans and Cohen, 2004). In other words, audible safety encompasses perceived traffic noise control and is practically perceived environmental control. Thus, ***we regard perceived control as a conceptual link between a narrow perspective focussing on adverse noise exposure on the one hand and a more comprehensive – salutogenetic – perspective highlighting health promoting resources on the other***. What is needed to create audible safety is not just quietness in the acoustic sense, but a variety of sounds and sensual impressions as operationalised and captured by arousal and valence as well as exogenous and endogenous motivation dimensions. In this vein, recent studies have concluded that quiet areas are not necessarily restorative areas – and vice versa (Cobianchi et al, 2019; Lavia et al., 2016, 2020; Payne and Bruce, 2019; Torresin et al., 2012). The interplay of environmental perceptions and appraisals, reasons for seeking out a certain place, expectations of activities, feelings and well-being attached to a place (Payne and Bruce, 2019) need further investigation, however, and may involve going beyond the audio-visual to a multi-sensory approach and appreciating the role of local biodiversity for (multi-sensory) environmental quality. Currently, there is no evidence of whether and how arousal and valence as well as exogenous and endogenous motivation can interact with social determinants of vulnerability. However, we may assume that these dimensions can explain differences in perceived coping options and subsequent stress responses.

The notions of audible safety and perceived environmental (traffic) noise control make the link between social and environmental determinants of vulnerability rather obvious in planning procedures. Determinants like trustworthiness of planning authorities and institutions

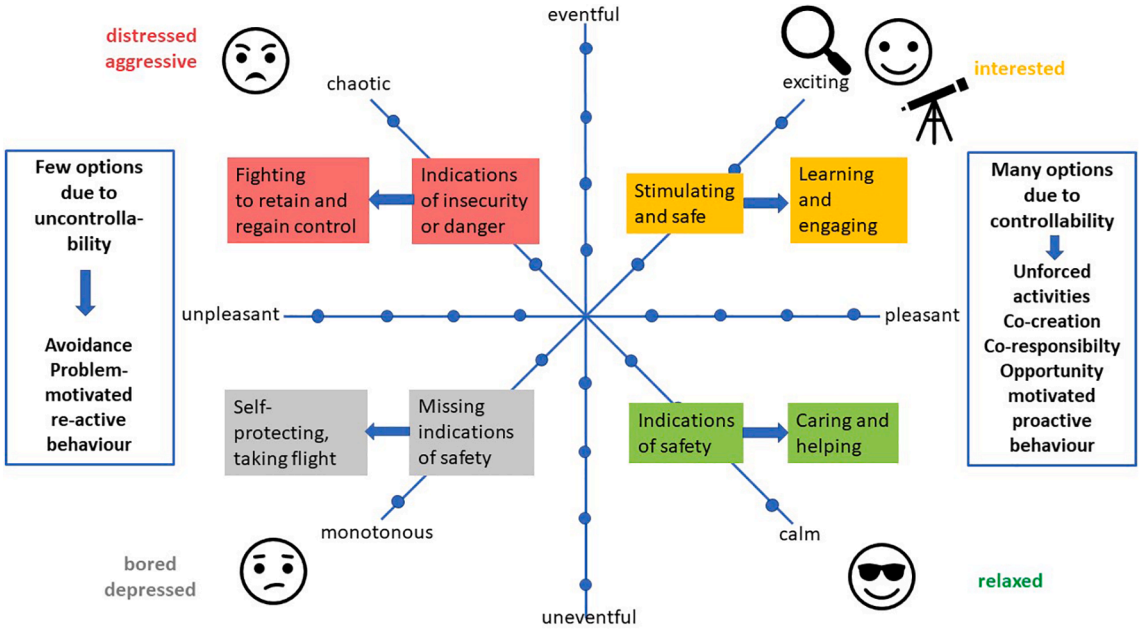

Fig. 3. Relation between environmental perception, appraisal, and cognitive modes (own by Natalie Riedel figure based on Andringa and Lanser, 2013).

(including being free from bias), recognition of concerns and having a voice, consistent applications of rules and procedures rules, access to relevant information and transparency are facets of perceived fairness (Asensio et al., 2017; Maris et al., 2007) and ingredients of a high trust environment. This means that audible safety is mirrored by the governance of audio-visual environmental quality (Andringa et al., 2013). Exposure to transportation noise and its management are intrinsically linked (Maris et al., 2007; Stallen, 1999). Planning can contribute to perceived environmental control by seeking to open up behavioural and planning options. Conversely, planning can add to perceived *un*controllability by creating bureaucratic situations making people seek help in vain and aggravate adverse health outcomes, particularly annoyance (e.g. Suau-Sanchez et al., 2011).

5. Establishing a high trust environment for more environmental health equity and environmental justice

The cognitive-behavioural processes and approaches described in relation to vulnerability above require a high trust environment – both environmental-audio-visually and procedurally. To establish such an environment, we see three fields of action: (1) developing a theoretical and methodological groundwork and multi-/interdisciplinary training of students and professionals, (2) introducing comprehensible information and inclusive participation methods, and (3) creating supportive institutional frames and governance modes.

5.1. Theoretical and methodological groundwork and multi-/interdisciplinary training of students and professionals

Professionals in health impact assessment emphasise the generics, rather than the specifics. In order to understand differences in effect between population groups, we need to improve our understanding of causes of vulnerability and intervention opportunities. As argued above, 'non-acoustic factors' help contextualise exposure–response-relations and recognise the relationships between environmental appraisal, emotions, cognitions, and participation. To advance the state of health impact assessment and noise/sound action planning, we advocate for developing a theoretical and methodological groundwork that

- aligns the 'traditional' noise impact / noise control approach (health protection, directed at adverse noise exposure) with the "soundscape" approach (health improvement, salutogenesis, as is the objective of the ISO series 2014; 2018; 2019),
- is the basis for a discourse, or, ideally, represents a consensus on the definition of 'non-acoustic factors',
- builds additional noise and health indices reflecting citizens' perceptions and appraisals in addition to the noise indicators L_{den} and L_{night} as well as DALYs and NafP,
- harmonises data collection (e.g. by providing survey templates), reporting and analytical strategies of (inequalities in) 'non-acoustic factors' in relation to mental, and physical health outcomes (including noise annoyance) as well as political participation,
- leads to comparability in definitions and operationalisations of environmental and social determinants of vulnerability,
- builds an evidence base on the interlinkages and causal mechanisms of acoustic and 'non-acoustic' factors from a local health equity and environmental justice perspective (e.g. inclusion of driving forces of exposure distributions, interactions of factors across life domains, differences in effects of 'non-acoustic factors' between groups characterised by various determinants of vulnerability),
- opens up ways to capture various determinants of vulnerability to transportation noise exposure qualitatively if its quantification is unreliable or not possible due to data gaps,
- defines 'non-acoustic factors' to be addressed in procedures (noise management) and outlines with which kind of procedures we can address which kind of 'non-acoustic factors',
- sets the ground for multi-/interdisciplinary training that establish procedures for integrating new and growing scientific evidence in the policy-making process and for communicating environmental risks, break down disciplinary silos, encourage inter-sectoral collaborations and specialise in local assessments.

We call for observational and intervention studies linking socio-environmental psychological and epidemiological strands of research in order to determine causal pathways and to design standards on survey and qualitative methods, contextual data sources, objective and subjective measures and metrics as well as analytical strategies. The objective of these studies is to explore how 'non-acoustic-factors' can be used as leverage to protect and improve health outcomes and alleviate

health inequities. A common conceptual framework is at the core of the groundwork. This framework should illustrate how interventions involving exposures to transportation noise, environmental and (psycho)social resources can make a substantial difference to social / socio-spatial variations in adverse exposures, determinants of vulnerability, and ultimately, health inequities. In doing so, the framework will draw on concepts of environmental justice and cumulative risk assessment emphasising the role of psychosocial resources as effect modifiers in the association between adverse environmental exposures and physical health outcomes (e.g. Bolte et al., 2011; deFur et al., 2007; Gee and Payne-Sturges, 2004; McEwen and Tucker 2011; Morello-Frosch and Shenassa 2006). Regarding the relationship between trust and perceived environmental control, this framework should explicate audio-visual stimulus characterisations and behavioural cognitions (in general: coping repertoire; in particular: engagement-specific self-efficacy, institutional knowledge, expectations of outcomes during participation processes) as conceptual links between unequal exposures and unequal participation. Moreover, such a framework should elaborate on how (and why) population characteristics intersect to generate explanatory mechanisms of social and environmental determinants of vulnerability in relation to both health effects and planning procedures. As suggested by Brown and van Kamp (2017), interventions to be evaluated against backdrop of this framework could address (1) sources of noise exposures (changing emission levels by changing traffic flows and introducing curfews), (2) the path between sources and receivers (intercepting the path by installing noise barriers and insulating dwellings), (3) relevant infrastructures (by opening or closing roads, railways, runways or introducing measures of planning control like zoning and buffer requirements), (4) situational and physical factors (by providing restorative green spaces, quiet sides and quiet places, environmental quality in the neighbourhood), as well as (5) education (e.g. reducing personal exposure by identifying behavioural options) and communication (e.g. changing attitudes towards sources, planning interventions and planning authorities by making arguments and reasons for changes in noise levels transparent). All these five approaches have the potential to change environmental and social determinants of vulnerability by changing distributions of adverse and salutogenetic exposures as well as planning and participation procedures towards environmental justice. However, they will need to be closely monitored to avoid unwanted side-effects on determinants of health and vulnerability (e.g. as a consequence of relocations of social and economic activities, social selection and residential displacement; additional bias in participation). Apart from a general lack of intervention studies, challenges of health equity and environmental justice have not been systematically pursued as a subject of intervention study design and evaluation. The scarce evidence mostly relates to exposure sources and has produced mixed results regarding effects on exposure distributions and/or health gains. For example, the implementation of a new traffic circulation plan generated an improvement in air and noise pollution among residents with a higher income at the expense of those with a lower income in the Hague (Kruize 2012). Similarly, residents with a socio-economically higher position profited from the introduction of low-emission zones in Rome to a larger extent (Cesaroni et al., 2012). However, a congestion charge was assessed to narrow socio-spatial differences in air pollution and life expectancy in greater London (Tonne et al., 2008).

Indicators of positioning in social power relations may therefore offer a first analytical step to capture vulnerability as a group characteristic and evaluation criteria of intervention studies. As proposed by the PROGRESS Plus initiative, these indicators should go beyond socioeconomic circumstances, include and intersect with other dimensions like socio-cultural aspects of gender and ethnicity, or age-related conditions (O'Neill et al., 2014; Cochrane Methods Equity website). The choice of which indicators are critical for health inequities depends on the social and environmental context. In assessing the health impacts of noise action plans and comparing the impacts against alternative solutions, differences between population groups should be accounted for. Such research may also encompass exploring different vulnerability assumptions for disability weights in the calculation of DALYs.

Generally, health equity and environmental justice are infringed whenever control over one's environment as an essential functional capability is constrained despite being avoidable by means of (planning) institutions. Societies are heterogeneous, however, and distributions of chemical, physical, and social stressors and resources do not always follow a social gradient (like attitudes and dispositions). For this reason, an evaluation of interventions based on the envisaged conceptual framework has to go into the hypothesised mechanisms of the intervention approaches outlined above. Thus, the evaluation will have to make explicit how environmental, social, and biological determinants of vulnerability become effective in the intervention. The model protocol for intervention studies (Brown and van Kamp 2017, table 20, p. 39) may serve as a useful tool. This model protocol covers repeated measurements of different types of response measures, including activity interference, coping strategies, attitudes, and expectations, while considering steady-state controls. In the context of environmental justice, this protocol has to be embedded in - or rather - expanded by driving forces of inequities.

Expertise from environmental health, soundscape and spatial planning research must be joined to deliver guidance on how to assess, anticipate, and evaluate (unequal) health effects of noise / sound action planning under different cultural, climate and biodiversity conditions. This guidance should include technical advices and standards on how to implement 'health equity' in policies and legislation and as part of a proactive ecological assessment. The current initiative on the ISO Technical Standard on 'Characterising non-acoustic factors for acoustic, soundscape quality and annoyance assessments' (ISO TC/43/SC1/WG62, Fenech et al., 2021) is a starting point to develop a guide for urban and environmental planning (textbox 3).

To bridge the gap between science and policy-making, this guide has to be simple, short and concise to the point in order to effectuate a change in planning practice. Considering the relevance of participation and the Aarhus convention (1998), this guide should target citizens as well as non-governmental organisations.

5.2. *Introducing comprehensible information and inclusive participation methods*

Without being informed properly, participation is hard to achieve. The current practice of noise impact assessment is rather difficult to communicate, with the noise (L_{den}, L_{night}) and health (DALYs) indicators plus their underlying assumptions being rather detached from people's experiences and situational expectations. At the same time, an increase of annoyance levels has been observed at comparable noise levels in term of L_{den} (in particular due to aircraft noise increase), which might indicate a shift towards more sensitivity to environmental health concerns in society, self-expression and self-efficacy in recent years. Thus, it is all the more important to establish a common language and understanding of what is at stake at particular decibel values, presenting noise annoyance and sleep disturbance as a serious stress response and taking 'non-acoustic factors' into consideration. Otherwise, citizens do not feel recognised and mistrust is bound to arise.

A *complementary* mechanism is needed for conveying results from health impact assessments to the public, using a combination of intuitive graphics and audio-visual demonstrations as already done for aircraft noise, like visual maps about noise events at airports (Department of Transport and Regional Services Canberra, 2000; Anderson Acoustics Limited, 2017, p. 23) and for high speed railways and wind turbines (ARUP Soundlab website). Approaches from citizen science could be employed to develop a meaningful metric that provides information about what people can perceive and what causes distress. The HARMONICA index was a valuable step in this direction where the public was invited to take part in laboratory experiments and be involved in the development in this a-dimensional index, with values

Textbox 3
Key objectives of the ISO Standard Initiative ISO TC/43/SC1/WG62

a) To reach a consensus on the definition and a conceptual framework of 'non-acoustic factors', given that they are a key aspect of the noise – health relationship.
b) To bridge the language gap between 'non-acoustic factors' for noise health outcomes (annoyance, self-reported sleep) and 'non-acoustic factors' for soundscape.
c) To reap the advantages by using a harmonised framework, not just for researchers but also when synthesising data (e.g. for the next revision of country-specific adaptions of WHO Environmental Noise Guidelines) and for those planning interventions that address non-acoustic-factors in addition to acoustic factors.

ranging from 0 to 10 (Mietlicki et al., 2015; Noise in EU website). HARMONICA distinguishes between background noise and noise peaks during different times of the day and uses the colouring of traffic lights (red, yellow, and green) to assess local noise situations.

By covering background noise and noise peaks, the HARMONICA index is in line with results from a study from Manchester University, showing that loudness, frequency and time of noise event are the most important criteria for environmental appraisal (Hooper et al., 2009). However, the HARMONICA index does not account for predictability / foreseeability of noise events, which is important for residents to adapt and maintain perceived environmental control / audible safety (Haubrich et al., 2020a; Haubrich et al., 2020b; Lavia et al., 2020; Stallen, 1999). Trust can be easily lost and noise annoyance can be aggravated if communications of noise abatement measures are misleading. This happened in the case of the so-called 'Lärmpause' (noise respite) at Frankfurt airport that made residents expect a consistent interruption of noise events instead of just a reduction of flight movements (Schreckenberg et al., 2016). This critical point of losing residents' trust underlines the need to develop a metric that characterises the noise stimulus in an accurate and comprehensible way – without ending up with an unstructured box of many indicators that confuses citizens, officials, and policy-makers alike. Adaptive maps could be co-produced together with citizens that include information on L_{den}, L_{night}, and residents' experience with - and perception of - main noise sources plus social, environmental and biological determinants of vulnerability.

'Digital Methods for participatory spatial analysis (DiPS)' (Köckler and Simon, 2019) aim at reaching more and other people for healthy urban development and gathering different perceptions and types of knowledge. Conducted in the context of the noise action planning in the city of Bochum, Germany, the DiPS_noise project is an example of innovative and inclusive community-engaging method in a multi-lingual urban setting. At the core of this project is a semi-standardised application combining a survey with geo-information available in six languages and useable on mobile phones and computers. Using various channels from advertisements in regular newspapers, press releases and social media targeting, the project aimed at recruiting a broad range of population groups. Without being obliged to register, participants could locate noisy places, quiet places and noise in residential surroundings, respond to health-and planning- related questions and rate the usability of the mobile application. Results on participants and app usability revealed (1) lacking procedural knowledge, (2) lacking engagement-specific self-efficacy, (3) time constraints, and (4) the feeling of not being addressed to be main reasons for non-involvement in public participation within the last five years. Half of the participants expected not to have their voices heard if they decided to participate. This stresses the need to be transparent about how participation results can inform the decision-making processes in noise action planning as well as in adjacent health-related (planning) policies.

Digital applications can be used to enable citizens to assess audio-visual environmental qualities, as well. For instance, the MoSART mobile phone app asks citizens to rate their environment on the dimensions of arousal and valence as well as exogenous and endogenous motivation and to reflect on their core affect and activities while spending time in this environment (Soundappraisal website). Further, environmental simulators invite citizens to select environmental features – 'non-acoustic factors' – in order to create different audio-visual impressions of places that could be developed into restorative places, as shown by the project DeStress (Destress website). Similarly, in the European project ANIMA (Aviation Noise Impact Management through novel Approaches), the mobile application AnimApp was developed in order to allow residents in (but not restricted to) airport regions to assess the momentary perceived sound- and landscape at different times of day, together with the location and noise levels by means of the mobile device with the user's permission (Ganic et al., 2021). Sharing these audio-visual experiences among the public, officials and policy-makers can transform the rather 'abstract' subject of environmental noise/sound impact assessment fairly specific and concrete for participation purposes.

Provided that digital approaches manage to realise a truly inclusive design for participation, they have the potential to add to local knowledge, qualify the local evidence base and feed into participatory monitoring systems. If taken seriously by officials and policy-makers, this type of evidence could help achieve more health equity by

- sharing emotional responses to environmental exposures and resolving upon relevant (health) outcomes in a joint effort (while trying to make clear the harmfulness of noise exposure),
- giving an effective voice to less eloquent citizens, learning about their individual constraints, and providing citizens with adequate tools,
- making optional scenarios obvious and disclosing (perceived and objective) planning constraints,
- discussing variable, setting-based adaption strategies going beyond mere noise control (providing possible answers to how to shape life instead of giving up to adverse living conditions),
- allowing residents to decide on both abatement and compensatory measures, i.e. making them effective agents and owners of decisional power – that is by giving them an actual choice.

These few bullet points give an idea of how trust in responsible planning and source authorities and perceived environmental control are interrelated. '[…] control beliefs can be associated with poorer health outcomes […] when expectations for control are high but opportunities to exercise it are constrained. […]' (Taylor and Seeman, 1999, p. 211). As shown in the empirical test of MOVE (Köckler, 2017) (section 4.1), social network in terms of relevant acquaintances[8] and home ownership emerged as additional condition and object resources predictive of engagement-specific self-efficacy and performed engagement among older residents. These two resources correlated with the

[8] Operationalised by knowing someone from a political party, administration, expertise in legislation, thereby having access to relevant information through participants' social network (Köckler, 2017).

most favourable combinations (lower exposure to traffic noise, higher perceived noise control, higher generalised self-efficacy, higher engagement-specific self-efficacy, higher communal mastery, more frequent intended and performed engagement – and higher education) in the study on older residents in the Ruhr Area (Riedel et al., 2021a). Social networks could therefore be a vehicle to minimise barriers and risks in the e-participation of noise/sound action planning. Aside from its value of as object, the notion of (home) ownership could be qualified by symbolic values (van Kamp, et al., 2019). Ownership could refer to both material benefits (like having an economic share in airport development) and psychosocial benefits (like sharing knowledge, decisional power and accountability of distributional outcomes) that may serve as a means to encourage co-creative and co-productive engagement among residents. Such ownership may help overcome health inequities reinforced by the traditional 'ownership' as part of individual's social position. Thus, environmental resources from sound-/sensescape-related research may not only give rise to psychosocial resources, but psychosocial resources may also foster interest in environmental qualities through 'ownership'.

5.3. Creating supportive institutional frames and governance modes

At last, the theoretical and methodological groundwork, comprehensible information and inclusive participation methods can become (more) effective only if supported by an institutional frame and governance. For instance, Wales enacted the Noise and Soundscape Action Plan 2018 – 2023 (Welsh Government 2018a) that is placed alongside the cross-cutting Planning Policy (Edition 10) (Welsh Government 2018b) and within an overarching policy framework (Well-Being of Future Generations (Wales) Act, 2015). In this way, the Welsh government created an institutional frame for noise-/soundscape-related policies that makes environmental planning

- develop a multi-dimensional understanding of health and well-being (economic, social, environmental, and cultural),
- aim at a gradual shift from looking at noise effects on 'the average person', or setting noise controls based on averaged curves (which protect the population at the lower risk),
- adopt a multi-disciplinary approach,
- act locally and holistically – together with urban planning – despite sectoral thinking oftentimes directed at national levels,
- be dedicated to promoting health and well-being, and
- monitor the achievements with respect to wellbeing in the local area.

Within such an institutional frame, environmental and urban planning is able to implement local (soundscape) planning policy cycles from setting goals to conducting evaluations, therefore intersecting with community-engaged action cycles dedicated to health promotion. These actions have to include formal and informal planning instruments contributing to a regulation of traffic flows as well as protection of sensitive social infrastructures and land uses. Sensitive to local planning contexts, diverse stakeholders' and citizen's / residents' settings, policy cycles will be constantly developing, initiating and responding to local changes and to the needs of groups affected by determinants of vulnerability. Furthermore, such policy cycles can open up recurrent opportunities for participation throughout the reiterative planning process, thereby increasing participation inclusiveness and social cohesion among present and future residents (and informing noise impact assessments). Thus, participation does not take place on single occasions, but is a continuous element of an 'agile' noise-/sound related environmental governance (Xiao et al., 2018).

Currently, local environmental planning usually follows national policies, not requiring to figure out locally specific impacts and to monitor equity impacts continuously. When implementing national policies at the local level, it is therefore of utmost importance to bridge the disconnect between national and local approaches. Housing development projects can set the stage for establishing such connections, since both environmental and urban planning have to clarify residential target groups, assess its environmental / ecological impact on the local environment and prevent gentrification. Restoration needs can be drawn from inclusive participation methods as described above. Participation results may then trigger more nuanced and ambitious noise-/sound related quality standards, such as in the City of Brighton and Hove where a series of participatory soundscape planning activities informed the development of multiple co-designed soundscape interventions (Alves et al., 2015; Easteal et al., 2014; Lavia et al. 2012; Lavia et al., 2015) and the development of a theoretical framework for a soundscape planning process based on people as co-specifiers of planning goals and objectives (Xiao et al., 2018). Seeking to exhaust possibilities for noise reduction and improvement of environmental qualities as much as possible, urban and environmental planning acknowledges the full realm of sounds and sensory effects. Local governance could commit itself to creating sound-/sensescapes that can foster restorative processes in residents' mind, enabling them to pursue self-directed activities, to enter a co-creative mode and to spend cognitive resources on place-making despite stressful experiences in other life domains (section 4.2). In this way, it could help ease inequity effects from other politics (in line with 'health (equity) in all policies'). In this vein, a recent commentary made suggestions on what planning and health professionals and officials, the EU, (local) parliaments and committees, non-governmental and civil society organisations, and citizens can do in order to 'move noise action planning towards more environmental health equity' along five propositions (Riedel et al., 2021b).[9]

To facilitate supportive institutional frames and governance processes, the European Commission ought to take overarching leadership. The END and its transposition in national legislations should require measurement and assessment standards describing a high trust' environment, both audio-visually and procedurally, informed by the theoretical and methodological groundwork and innovative community-engaging methods. It is only through European-wide obligations that comparability of standards of environmental quality and policy-making can be achieved. Importantly, END standards should apply to both current urban situations, urban regeneration programmes, as well as new developments as outlined by land use and building plans. Given the need to balance different stakes when setting up these plans and programmes, inter-sectoral collaborations between urban planning, health and environmental planning departments should become mandatory to reach a significant reduction of noise levels and to promote salutogenetic resources. Otherwise, if the willingness to follow the notion of high trust environments at the local level varies, additional inequities within and between European countries could be generated. Moreover, the END needs to consider other (increasingly) important noise sources (e.g. wind turbines) and broadening its spatial coverage beyond urban agglomerations and major infrastructures in order to not overlook substantial parts of population groups affected by noise exposure and not to induce unfavourable social-spatial aftereffects. In addition to setting environmental standards valid across Europe, changes to the END should include instructions on integrating vulnerability concerns, comprehensive modelling and distributional effects of noise action

[9] Arguments are structured according to the five prepositions: (1) Implementing noise action planning effectively requires noise and health in all (planning) policies. Binding standards for noise-related environmental quality and inter-sectoral collaboration across political and administrative levels help establish this requirement. (2) Noise action planning should consider differences in health effects (different vulnerabilities). (3) Distributional effects of noise action plans have to be evaluated. (4) The assessment of the total noise exposure is necessary to estimate the extent of inequalities in environmental exposures. (5) Public information and consultation according to the END involves empowerment and innovative methods to enable effective and just civic engagement.

measures, methods on multiple burdens, as well as specifying the Aarhus convention within the END (Riedel et al. 2017b). Required to catch up with scientific progress, annex II and annex III of the END could refer to guides that *trans*-disciplinary expert panels have consented to and are evaluating on a regular basis (like the ISO Technical Standard series) and that are made mandatory in national legislation. Responsible policy-makers should be obliged to take part in trainings developed from the theoretical and methodological groundwork. **Generally, integrating 'non-acoustic factors' in policies must not imply distracting the public from the harmfulness of transportation noise exposure, but rather contributing to attenuating exposure and effect differentials instead**.

6. Conclusion: Outlook for a joint transdisciplinary research initiative for health equity and environmental justice

This workshop report sketched enormous needs for both research and action. We close it by reminding us that, "[…] there is plenty of evidence to enable action" – both for universal measures protecting and promoting health of all as well as for "targeted measures designed to reduce exposure particularly in deprived populations […]" (Science for Environment Policy, 2016: p. 5). What is needed is a joint trans-disciplinary initiative that aims to develop a theoretical and methodological groundwork dealing with the interlinkages of acoustic and 'non-acoustic factors' from a local health equity perspective in European countries. To make a substantial difference towards health equity and environmental justice, such an initiative has to be concerned with introducing comprehensible information and inclusive participation methods as well as creating supportive institutional frames and governance modes within different European institutional settings. Experiences and results from this initiative may inform similar endeavours in other countries beyond Europe. When doing so, however, these endeavours will have to be aware of varied actors and power constellations in places where more or less informal rules prevail (e.g. in informal settlements).

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Natalie Riedel: Conceptualization, Writing – original draft, Writing - review & editing, Funding acquisition. **Irene van Kamp:** Writing - review & editing. **Stefanie Dreger:** Writing - review & editing. **Gabriele Bolte:** Writing - review & editing. **Tjeerd Andringa:** Writing - review & editing. **Sarah R. Payne:** Writing - review & editing. **Dirk Schreckenberg:** Writing - review & editing. **Benjamin Fenech:** Writing - review & editing. **Lisa Lavia:** Writing - review & editing. **Hilary Notley:** Writing - review & editing. **Rainer Guski:** Writing - review & editing. **Daniel Simon:** Writing - review & editing. **Heike Köckler:** Writing - review & editing. **Susanne Bartels:** Writing - review & editing. **Miriam Weber:** Writing - review & editing. **Marco Paviotti:** Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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